Machine learning non-local closures for 3D turbulent flows over a back-step

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Abstract: In this work we explore the capabilities of deep recurrent neural networks to act as nonlocal closure models for turbulent 3D flows. In more detail, we employ data-informed energy-consistent closures for a turbulent flow over a back-step. Through our closure scheme, we aim to accurately capture the evolution of the boundary and separation layers generated by a flow past a back-step. We employ a coarse-scale discretization of the governing equations together with the neural net closures to evolve in time the fluid flow. Utilizing recurrent and convolutional layers, we capture nonlocal spatio-temporal effects, induced by the large scale dynamics of the flow. In addition, appropriate physical constraints corresponding to energy conservative terms of the equations are introduced during training to the improve numerical stability of our predictions. Our model is able to accurately capture the evolution of the closure terms even for very coarse-scale resolutions. Finally, we contrast our data-informed energy-consistent approach and standard LES closures, comparing accuracy and computational cost.